Integration of Solar Process Heat into an Existing Thermal Desalination Plant in Qatar

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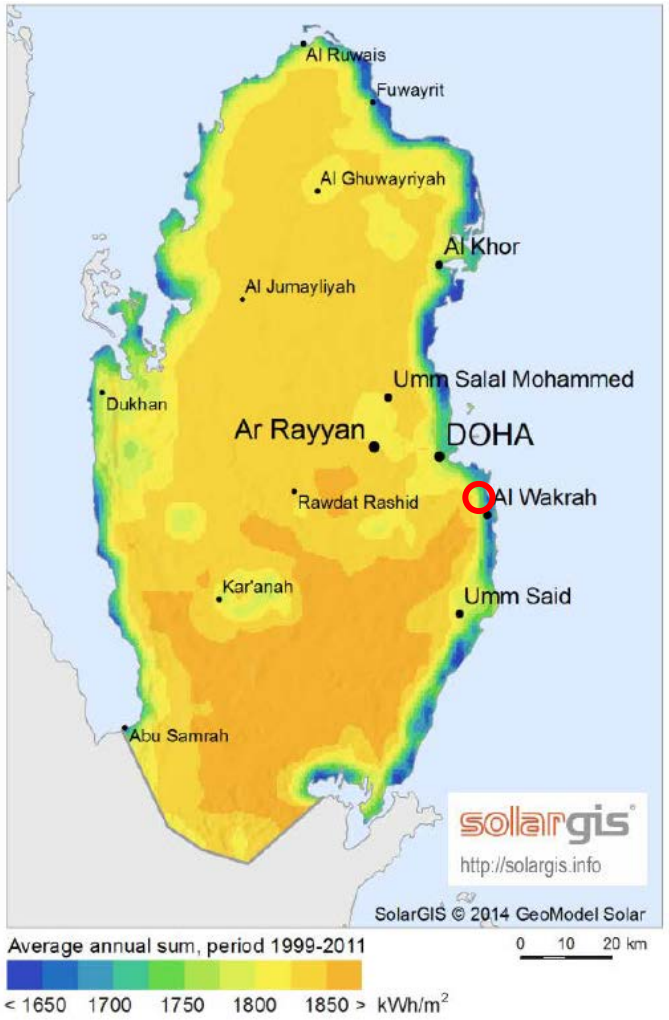
Overview of Content

1. Solar Resources and Market Situation in Qatar
2. Solar Hybridization Options
   a) DSG: Direct Steam Generation – No Storage
   b) TES: Thermal Oil with 6h Molten Salt Storage
3. Techno-Economic Evaluation of Both Options
4. Feasibility of Solar Only Desalination
5. Summary

Source: DLR

Qatar Country Facts

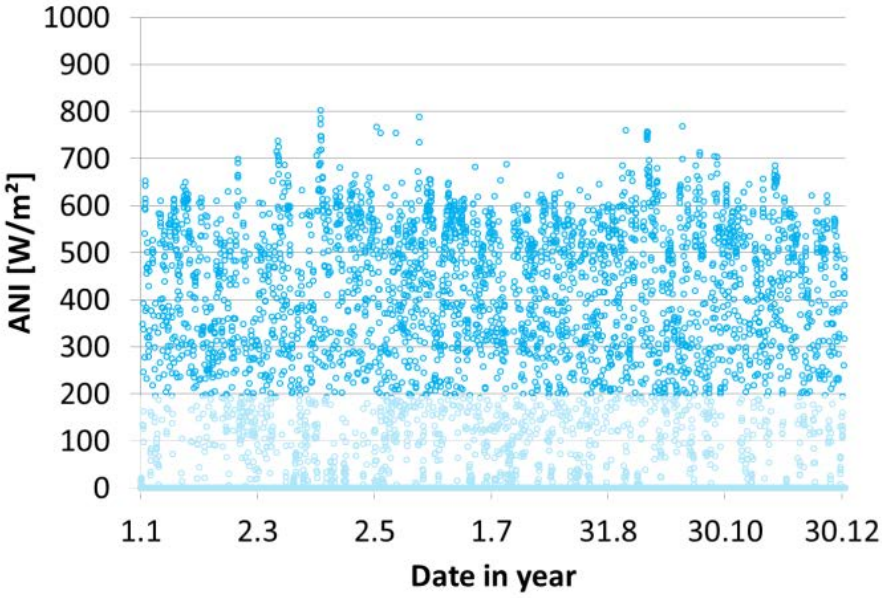
- Peak power demand in 2014: 6500 MW
- Avg. electricity consumer price: 33 US-$/MWh
- Average water consumer price: 1.40 US-$/m³
- Limited land availability
- 4th natural gas producer worldwide
  - Energy supply relies mainly on gas
- 200 MW solar tender announced



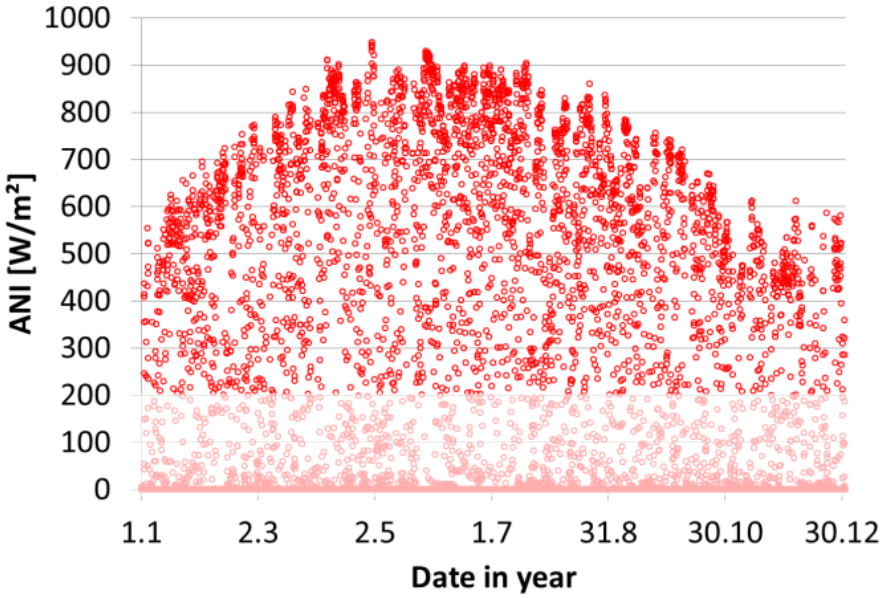
Source: SolarGIS © 2015 GeoModel Solar

Solar Resources in Qatar

Lusail, Qatar



Guadix, Spain



Aperture Normal Irradiance: $ANI = DNI \cdot \cos\theta$ (tracking axis south-north oriented)

Annual DNI: $1491 \frac{\mathrm{kWh}}{\mathrm{m^2 \cdot a}}$

Data Source: Meteonorm 7.1

Ras Abu Fontas Power and Desalination Plant

- Steam network:
  Saturated steam, 15 bar / 198°C
- Condensate temperature: 80°C
- Desalination steam demand
  - 10% at 198°C (vacuum ejectors)
  - 90% at 120°C (brine heater)
- Auxiliary firing to cover residual steam demand

Ras Abu Fontas Block B, Source: QEWC

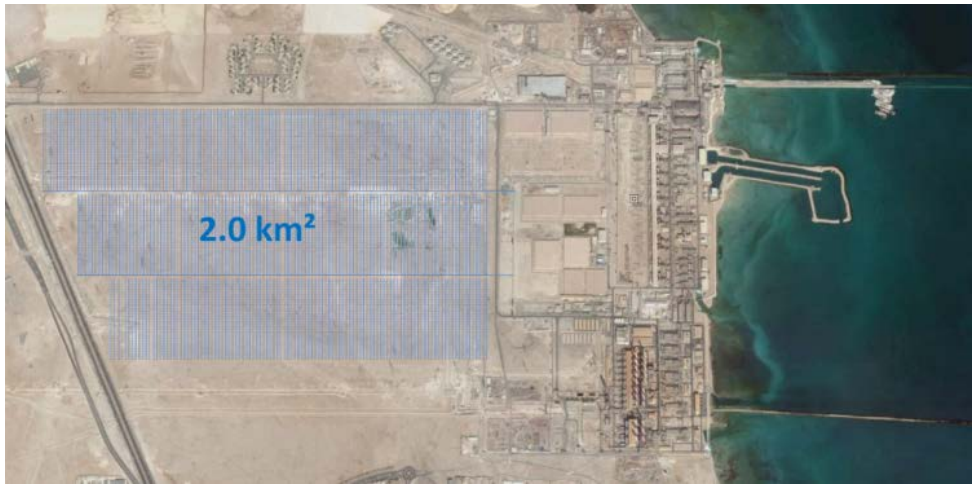
Gas turbines	
Capacity	2200 MW
No. Units	25
Waste Heat Steam Production	4260 t/h

Desalination	
Capacity	200 MIGD
No. Units	24
Steam Demand	4640 t/h

Investigated Solar Field Configurations

- Solarlite SL4600+ collectors
- Storage medium Hitec® salt
  - T_{freeze} = 142°C
- Techno-economic analysis using **greenius**

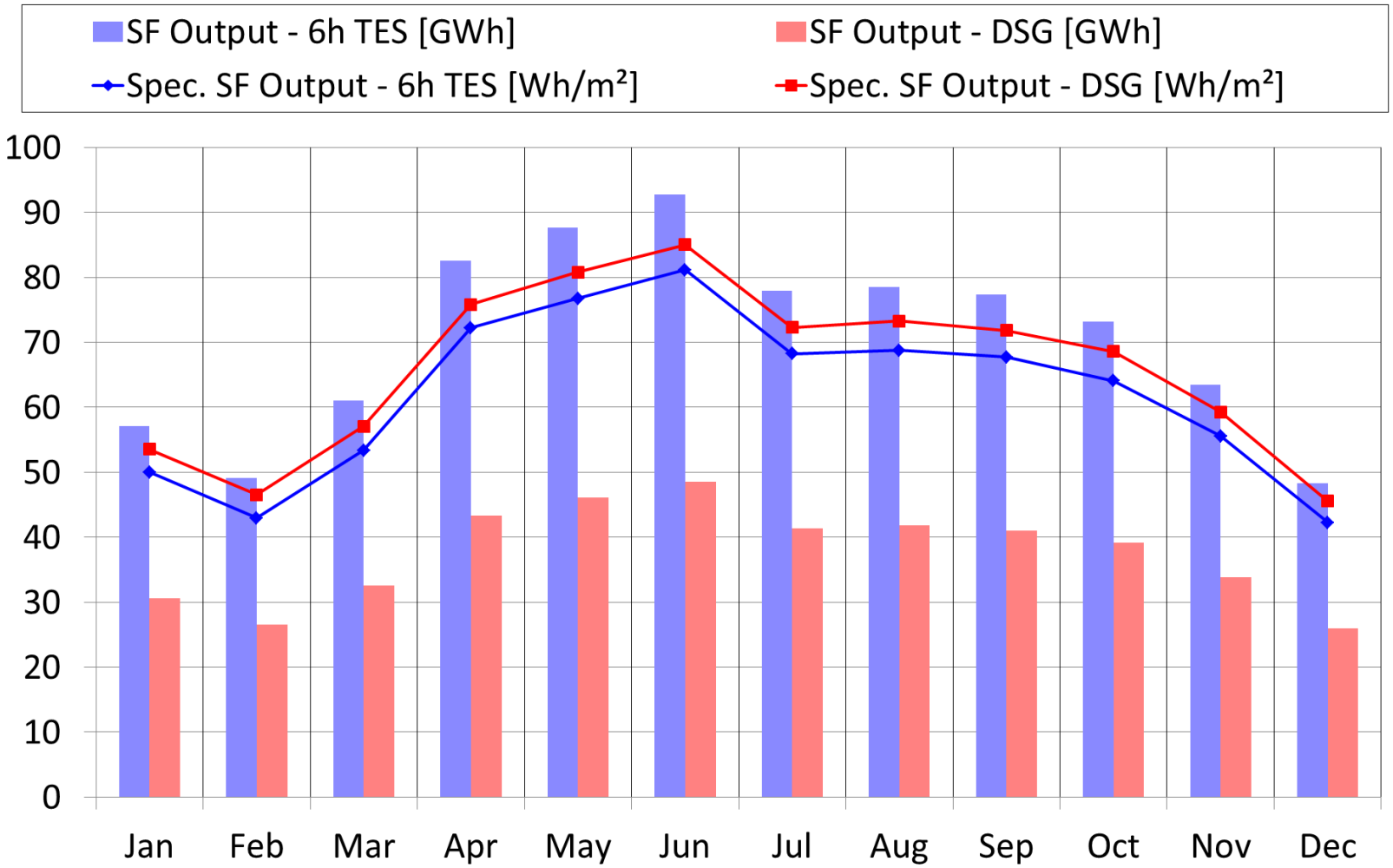
→ http://freegreenius.dlr.de



Ras Abu Fontas Power Plant, Source: Google Earth

Property	DSG No Storage	Thermal Oil 6h TES	Unit
No of Collectors	1080	2160	-
Solar Multiple	1	2	-
Nominal SF Output	240	480	[MW]
Aperture Area	570,000	1,140,000	[m²]
SF Inlet/Outlet Temperatures	80 / 198	220 / 320	[°C]
Storage Capacity	-	1440	[MWh]

Results – Monthly Solar Field Output



Results – Comparison of DSG and TES Option

Property	DSG No Storage	Thermal Oil 6h TES	Unit
Annual Solar Steam Production	661	1240	[1000 t]
Saved Fuel per Year	1.81	3.41	[10^6 MMBtu]
CO_2 Emission Savings per Year	108	204	[1000 t]
Mean Solar Field Efficiency	53.0	49.9	[%]
Solar Share	22	41	[%]

- 6% lower SF output with TES option
  - Due to higher operating temperature
- Seasonal variation is relatively weak

Economy: Levelized Heat Cost and Rate of Return

	DSG	Oil	Unit
CAPEX (incl. land cost ≈ 20%)	249 / 435	634 / 555	[Mio $] / [$/m²]
OPEX	5.9	8.3	[$/m²]
Levelized heat cost(LHC)	68	94	[$/MWh$_{th}$]

- LHC of fossil reference about 36 $/MWh$_{th}$ (fuel price: 8 $/MMBtu)
- Costs estimations by experts from QEWC, Solarlite and DLR
- Financing:
  - Discount rate: 10%
  - Equity share: 30%
  - Average debt interest: 2.5%

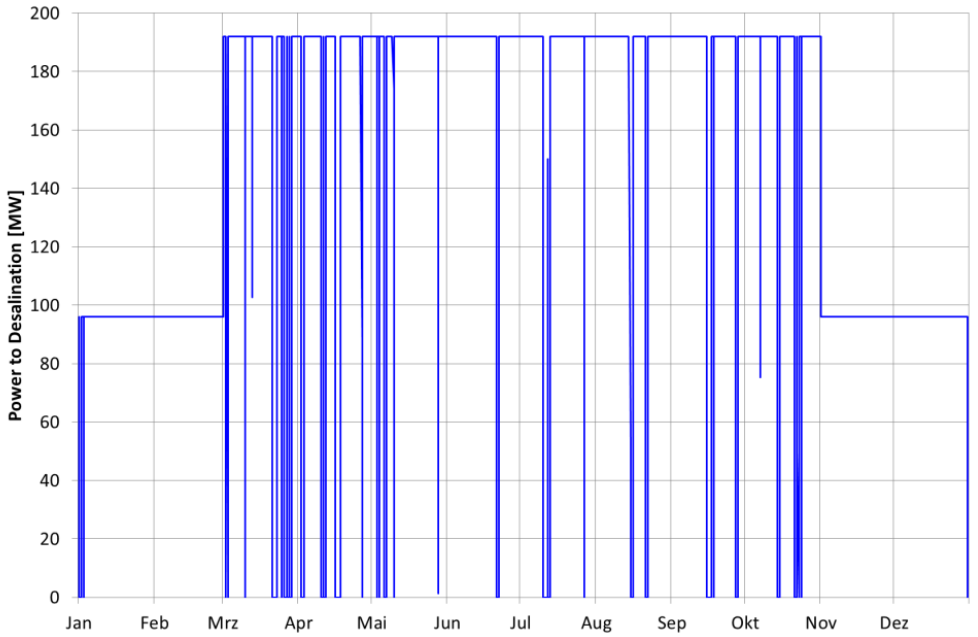
Total Fuel Costs / Opportunity Costs	[$/MMBtu]	4	8	12	16
Virtual Remuneration Tariff	[$/MWh$_{steam}$]	16.2	32.3	48.3	64.4
Internal Rate of Return (DSG option)	[%]	-5.5	4.8	13.1	21.4

Solar Only Operation

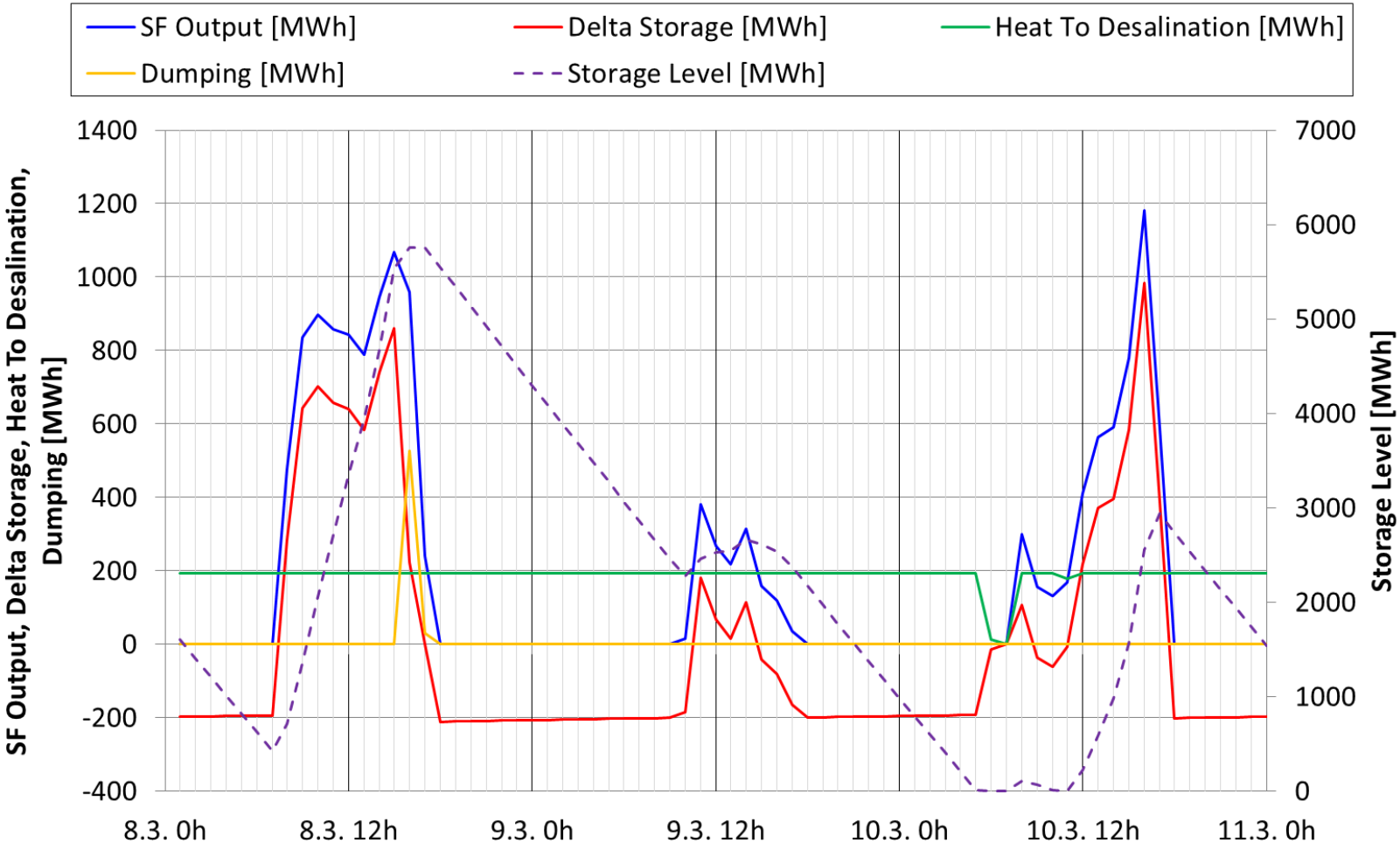
- Two desalination units (steam demand: 2 x 175 t/h)
- Minimum part load 80%
- In winter months (Nov – Feb) only one unit operating

Results 24h TES:

- Shutdowns per year : 30
- Capacity factor: 86%
- Dumping: 24%
- Levelized heat cost: +43%
  (compared to 6h storage)



Energy Flows with 24h Thermal Storage



Summary

- Qatar offers challenging environment for CSP
  - Limited solar irradiation potential DNI ≤1800kWh/(m²·a)
  - Limited land availability
- Solar energy as fuel saver becomes attractive (IRR > 5%) for fuel prices > 8 $/MMBtu
- TES with 24h capacity achieves capacity factors of 86%
  - 30 shutdowns per year require flexible desalination technology for solar only operation
- Co-generation of electricity and water not investigated

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THANK YOU
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